Reactions of Open-Pollinated Sweet Corn Cultivars to Stewart's Wilt, Common Rust, Northern Leaf Blight, and Southern Leaf Blight

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ABSTRACT

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Over 800 open-pollinated (OP) varieties of sweet corn were grown and named in the century prior to the development of hybrids, but only a few of the historically important OP cultivars exist today. Alleles that could improve disease resistance of modern sweet corn may be present in the OP cultivars still in existence. The objectives of this research were to compare 36 OP sweet corn cultivars to modern commercial hybrids for reactions to Stewart's wilt, common rust, northern leaf blight (NLB), and southern leaf blight (SLB), and to classify the OP cultivars based on phenotypic reactions to these four diseases. Plants were inoculated in 1994, 1995, and 1996 with *Erwinia stewartii*, *Puccinia sorghi*, *Exserohilum turcicum*, or *Bipolaris maydis*. Symptoms were rated on a whole-plot basis, and ratings were analyzed by analysis of variance (ANOVA). Means were separated by Bayesian least significant difference values. Some of the OP cultivars had phenotypes that were intermediate to moderately resistant to Stewart's wilt, common rust, NLB, or SLB, but none of the cultivars were more resistant than the best commercial hybrids. Distributions of ratings for rust, NLB, and SLB were less disperse for the OP cultivars than for commercial hybrids. Hence, the resistance of modern sweet corn germ plasm to Stewart's wilt, rust, and NLB appears to be greater than that of the OP cultivars. OP cultivars and four standard hybrids were placed into groups based on a hierarchical cluster analysis of disease reactions. The seven groups formed from the cluster analysis of disease ratings were considerably different than those formed from isozyme variation and morphological characteristics. The partial resistance of some cultivars, e.g., Golden Sunshine, Country Gentleman, Stowell's Evergreen, and Red, may be relatively diverse since these cultivars were placed in different groups based on isozyme and morphological variation. OP cultivars with moderate levels of resistance may be sources of resistance alleles not present in commercial hybrids.

The first commercially successful F_1 hybrid sweet corn, Golden Cross Bantam, was released by Smith in the early 1930s (17). Today, over 600 sweet corn hybrids are available commercially in the United States and thousands of new hybrids are developed and evaluated each year. These hybrids display a wide range of phenotypic reactions to prevalent diseases (9), indicating a considerable amount of diversity in commercial sweet corn for resistance or susceptibility to *Erwinia stewartii* (Stewart's wilt), *Puccinia sorghi* (common rusts), *Exserohilum turcicum* (northern leaf blight), *Bipolaris maydis* (southern leaf blight), and other maize pathogens. Nevertheless, the elite sweet corn germ plasm used presently in commercial hybrids probably is more similar genetically than the germ plasm composed of hundreds of open-pollinated (OP) cultivars grown prior to the development of hybrids.

Some authors in the popular press, such as Pollan (13), contend that the uniformity resulting from a field of F_1 hybrid sweet corn plants "violates one of nature's cardinal principles: genetic diversity" and suggest that "a field of genetically identical plants is much more vulnerable to disease." While an F_1 hybrid is less variable than an OP cultivar, the likelihood of a catastrophic epidemic in today's sweet corn crop relative to a crop based on OP cultivars depends on factors other than variation within the cultivar. Two of these factors include levels of disease resistance and the genetic basis of resistance. Elite commercial hybrids may be more genetically uniform than their OP ancestors for horticultural and agronomic traits of importance, but the genetic basis of resistance among modern hybrids may be more or less diverse than that of OP cultivars.

Over 800 OP varieties of sweet corn were grown and named in the century prior to the development of hybrids (19). Many of these OP cultivars originated from the northeastern United States (19). Commercial development of OP cultivars ended in the United States in the 1930s with the monumental success of Golden Cross Bantam and other sweet corn hybrids, due in part to the moderate Stewart's wilt resistance of these hybrids. Today, only a few of the historically important OP cultivars exist. These are maintained by organizations such as the North Central Regional Plant Introduction Station (NCRPIS) at Ames, Iowa, and the Seed Savers Exchange (1). Little is published about the reactions of these cultivars to prevalent diseases other than Stewart's wilt.

Alleles that could improve disease resistance of modern sweet corn may be present in some of the OP cultivars still in existence. Some of these resistance alleles may not occur in modern elite germ plasm since historically important inbred lines of sweet corn were developed from only a few OP cultivars, of which Golden Bantam, Stowell's Evergreen, and Country Gentleman were most prominent (5,6,20). In order to use the disease resistance that may occur in the OP germ plasm, the disease reactions of these cultivars must be identified and characterized.

The objectives of this research were to compare OP sweet corn cultivars to modern commercial hybrids for their reactions to Stewart's wilt, common rust, northern leaf blight (NLB), and southern leaf blight (SLB), and to classify the OP cultivars based on phenotypic reactions to these four diseases.

MATERIALS AND METHODS

Open-pollinated sweet corn cultivars, most obtained from the Seed Savers Exchange, were compared with commercial F_1 hybrids for reactions to prevalent diseases in 1994, 1995, and 1996. In 1994 and 1996, 32 and 36 OP cultivars and 384 and 357 hybrids, respectively, were evaluated for Stewart's wilt, common rust, NLB, and SLB. In 1995, 36 OP cultivars and 410 hybrids were evaluated for Stewart's wilt. Each trial included three replicates of cultivars and hybrids for each disease. Hybrids were divided into two groups based on endosperm mutation: *shrunken-2* (*sh2*) or *sugary* and *sugary enhanced* (*su1* and *se1*). Starchy phenotypes occur when *sh2* and *su1 se2* plants cross pollinate because the genes for sugary and shrunken endosperms are recessive. Each experimental unit was a single row about 3.2 m long with 10 to 15 plants per row. Trials were planted on 17 May 1994, 12 May 1995, and 24 May 1996.

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Plants were inoculated with *E. stewartii*, *P. sorghi*, *E. turcicum*, or *B. maydis*. Plants at the three- to four-leaf stage were inoculated with *E. stewartii* on 8 and 16 June 1994, 14 and 21 June 1995, and 20 and 26 June 1996 by wounding leaves in the whorl and introducing a bacterial suspension of about 10^7 CFU/ml into wounds (2). Urediniospores of *P. sorghi* collected from leaves the previous summer and stored in a freezer during the winter were suspended in water with a few drops of Tween 80. Urediniospore suspensions were sprayed directly into whorls of plants at the four- to seven-leaf stage on 15, 23, and 28 June 1994, and 21, 24, and 27 June 1996. Plants were inoculated with conidial suspensions of a mixture of races 0 and 1 of *E. turcicum* on 14 and 24 June 1994, and 19, 24, and 28 June 1996. Suspensions of about 10^3 conidia per ml were sprayed directly into leaf whorls. Conidial suspensions of *B. maydis* were sprayed directly into leaf whorls on 17 and 27 June 1994, and 18 June and 1 July 1996. OP cultivars were inoculated but hybrids were not inoculated with *B. maydis* in 1994. Cultures of *E. turcicum* and *B. maydis* were produced on lactose-casein hydrolysate agar (LCA) (21). Inoculum of *E. stewartii* was produced in nutrient broth shake cultures.

Standard disease assessment diagrams were used to rate symptoms on a whole-plot basis. Plants were rated for Stewart's wilt on a scale from 1 to 9 (18) on 11 to 13 July 1994, 12 to 14 July 1995, and 11 to 16 July 1996. Each row was divided into thirds, and each third was given a Stewart's wilt rating by two people. The six ratings per row were averaged for a single value for each experimental unit. In 1994, the percentage of the total leaf area with common rust symptoms was rated from 0 to 100% using a modified Cobb scale (11), and a modified Elliott and Jenkins scale was used to rate severity of NLB (10). In 1996, these two diseases were rated on a 0 to 9 scale where ratings were approximately the square root of the percentage of symptomatic leaf area. Rust was rated on 2 to 6 August 1994, and 22 and 23 August 1996. NLB was rated on 25 to 27 July 1994, and 19 to 21 August 1996. SLB was rated on a 0 to 9 scale on 26 July 1994 and 16 to 19 August 1996. Two people gave each row two ratings for rust, NLB, and SLB to reflect the range of predominate reactions of whole plants in each plot. Ratings were averaged for a single value for each experimental unit.

Disease ratings were analyzed by analysis of variance (ANOVA). Hybrid and cultivar means were separated by Bayesian least significant difference values (BLSD, $k = 100$). Percentage ratings for rust and NLB in 1994 were square root transformed, and hybrid and cultivar means were used to examine frequency distributions of 0 to 9 ratings for each disease. Distributions of the OP cultivars and *su1/se1* and *sh2* hybrids were compared within years by chi-square contingency tests.

The 36 OP cultivars and four standard hybrids were grouped for reactions to the four diseases by a hierarchical cluster analysis using Ward's method of SAS (SAS Institute, Cary, NC). Cultivar means for disease ratings (0 to 9 scale) were used in the cluster procedure. Groups of cultivars were differentiated based on an 0.7 average distance between clusters. Groups of OP cultivars formed from the cluster analysis of disease ratings were compared with clusters formed previously from isozyme variation (15) and morphological characteristics (16).

Table 1. Number of genotypes evaluated, means, standard deviations, and ranges of *su1/se1* hybrids, *sh2* hybrids, and open-pollinated (OP) sweet corn cultivars rated for reactions to Stewart's wilt, common rust, northern leaf blight (NLB), and southern leaf blight (SLB)

Disease, year, and germ plasm	n	$\bar{x}$	SD	Range
Stewart's wilt				
1994				
su1/se1 hybrids	132	3.2[a]	0.8	1.6–5.1
sh2 hybrids	251	3.1	0.7	1.3–5.0
OP cultivars	32	5.9	1.2	3.3–7.8
1995				
su1/se1 hybrids	170	4.9	1.1	2.7–7.7
sh2 hybrids	240	5.3	1.0	2.9–7.3
OP cultivars	36	6.8	1.1	3.9–8.3
1996				
su1/se1 hybrids	124	3.5	0.8	1.5–5.1
sh2 hybrids	232	3.7	0.7	2.1–6.1
OP cultivars	36	4.9	0.9	2.9–6.3
Common Rust				
1994				
su1/se1 hybrids	132	20[b]	13	0–46
sh2 hybrids	252	25	12	0–45
OP cultivars	32	25	8	10–43
1996				
su1/se1 hybrids	124	5.0[c]	1.0	0–7.6
sh2 hybrids	233	5.6	0.8	0–7.8
OP cultivars	36	6.0	1.1	3.5–8.5
NLB				
1994				
su1/se1 hybrids	132	26[b]	5	16–41
sh2 hybrids	251	25	6	3–42
OP cultivars	31	30	4	24–41
1996				
su1/se1 hybrids	124	5.1[c]	1.1	0.6–6.9
sh2 hybrids	232	5.0	1.1	0.1–7.6
OP cultivars	32	5.2	0.5	4.3–6.2
SLB				
1994				
OP cultivars	31	2.5	0.7	1.3–3.5
1996				
su1/se1 hybrids	123	3.2	1.4	1.0–7.5
sh2 hybrids	229	2.5	1.2	1.0–6.5
OP cultivars	34	5.1	1.1	3.3–7.3

[a] Stewart's wilt rated on a 1 to 9 scale (18).
[b] Severity of rust and NLB rated as the percentage of the total leaf area infected in 1994.
[c] Rust and NLB rated on a 0 to 9 scale in 1996, where ratings are approximately the square root of severity.

RESULTS

The OP cultivars and F_1 hybrids displayed a wide range of reactions to Stewart's wilt, common rust, NLB, and SLB. Means for Stewart's wilt ratings (1 to 9 scale) ranged from 1.3 to 7.8, 2.7 to 8.3, and 1.5 to 6.3 in 1994, 1995, and 1996, respectively (Table 1). For rust, means ranged from 0 to 46% leaf area infected in 1994 and from 0 to 8.5 (0 to 9 scale) in 1996 (Table 1). For NLB, means ranged from 3 to 42% leaf area infected in 1994 and from 0.1 to 7.6 (0 to 9 scale) in 1996 (Table 1). For SLB, means ranged from 1 to 7.5 (0 to 9 scale) in 1996 (Table 1). Data for SLB on hybrids were unavailable in 1994.

Stewart's wilt ratings were higher for the OP cultivars, as a group, than for the groups of *su1/se1* and *sh2* hybrids. Distributions of Stewart's wilt ratings for the OP cultivars were different from those for hybrids in all 3 years (Fig. 1), as indicated by highly significant chi-square values from contingency tests. Some OP cultivars had mean Stewart's wilt ratings that were higher than any of the hybrids (Table 1). None of the OP cultivars had Stewart's wilt ratings as low as the most resistant hybrid. The mean Stewart's wilt rating for all OP cultivars (5.9, 6.8, and 4.9 in 1994, 1995, and 1996, respectively) was at least one standard deviation above means for the hybrids in each year. Distributions of

Stewart's wilt ratings differed among *su1*/*se1* and *sh2* hybrids in 1995 and 1996, when the frequency of hybrids with low ratings was higher for *su1/se1* hybrids than for *sh2* hybrids. Distributions of Stewart's wilt ratings did not differ among *su1*/*se1* and *sh2* hybrids in 1994 when Stewart's wilt was less severe than in 1995 and 1996.

Distributions of rust ratings differed among *su1*/*se1* and *sh2* hybrids. The frequency of *su1*/*se1* hybrids with low ratings was greater than that for *sh2* hybrids (Fig. 2). The grand means for rust severity in 1994 and 1996 for the *su1*/*se1* hybrids were lower than those for the *sh2* hybrids (Table 1). About 18 and 33% of the hybrids were rated 0 for rust in 1994 and 1996, respectively, indicative of *Rp*-resistant reactions. None of the OP cultivars had *Rp*-resistance. When *Rp*-resistant hybrids were removed from the analysis, the OP cultivars had slightly less rust in 1994 and slightly more rust in 1996 than *sh2* hybrids. In both years, rust ratings were higher for OP cultivars as a group than for the group of *su1/se1* hybrids.

There was little difference among distributions of *su1*/*se1* and *sh2* hybrids for NLB ratings (Fig. 3). In both years, NLB ratings for OP cultivars were less disperse than those for the hybrids (Fig. 3, Table 1). Several hybrids had much lower NLB ratings than the OP cultivars, while none of the OP cultivars, except Pease Crosby, were as severely infected with NLB as some hybrids. Three OP cultivars, Clem Bennett, Queen Anne, and Tuscarora, had chlorotic and necrotic lesions indicative of reactions of the *Ht1* gene to races 0 and 1 of *E. turcicum*. Several hybrids, particularly *sh2* hybrids, had *Ht1*-reactions, and at least one hybrid, Day Star, had extended incubation periods indicative of resistance conferred by the *HtN* gene.

As a group, the OP cultivars were more susceptible to SLB than the hybrids. Chi-square values were significant among comparisons of distributions of OP cultivars, *su1*/*se1* hybrids, and *sh2* hybrids. None of the cultivars had SLB ratings as low as hybrids with the least amount of SLB (Table 1). Also, the frequency of *sh2* hybrids with low ratings for SLB was greater than that for *su1/se1* hybrids (Fig. 4).

Only a few OP cultivars had Stewart's wilt, rust, or NLB ratings as low as the standard hybrid with the lowest rating (Table 2). Golden Sunshine, Country Gentleman, and Red had the lowest Stewart's wilt ratings among the OP cultivars (3.6, 3.8, and 3.9, respectively) and were not significantly different from the standard hybrid, Miracle, which was rated 2.6 and is moderately resistant/resistant to Stewart's wilt when compared with other commercially available sweet corn hybrids (9). Country Gentleman and Red were rated 3.4 and 3.6 for rust and were not significantly different from Miracle and Sweetie 82, which were rated 3.5 and 2.9, respectively, for rust (Table 2). The levels of partial rust resistance of Miracle and Sweetie 82 are among the best available in commercial sweet corn hybrids, but they are inadequate to prevent reductions in yield under severe rust pressure (11). The NLB rating of 3.3 for the standard hybrid Summer Sweet 7710 was significantly lower than NLB ratings for all OP cultivars. Several commercial hybrids are more resistant to NLB than SummerSweet 7710 (12).

The hierarchical cluster analysis of mean ratings for Stewart's wilt, common rust, NLB, and SLB for 35 OP cultivars and four standard hybrids produced seven groups based on an average distance of 0.7 between clusters (Fig. 5, Table 3). Group 1 included four cultivars that were relatively susceptible to Stewart's wilt, rust, and NLB, and intermediate for SLB ratings (Fig. 5, Table 3). Group 7 included two Amerindian cultivars, Hopi White and Paiute Cross, that were relatively susceptible to all four diseases. The seven cultivars in Group 2 had low ratings for SLB, intermediate ratings for rust, and high ratings for Stewart's wilt and NLB. The 12 cultivars in Group 3 had intermediate ratings to all four diseases. Three cultivars (Country Gentleman, Golden Sunshine, and Stowell's Evergreen) and one standard hybrid (Sweetie 82) in Group 4 had low ratings for rust and SLB, and moderate ratings for Stewart's wilt and NLB. Stewart's wilt and NLB ratings were relatively low, and rust and SLB ratings were low to intermediate for the two standard hybrids (Miracle and SummerSweet 7710) and one cultivar (Red) that formed Group 6. Group 5 included seven cultivars that were relatively susceptible to Stewart's wilt and NLB and intermediate to susceptible for rust and SLB.

The seven groups of OP cultivars and four standard hybrids formed from the

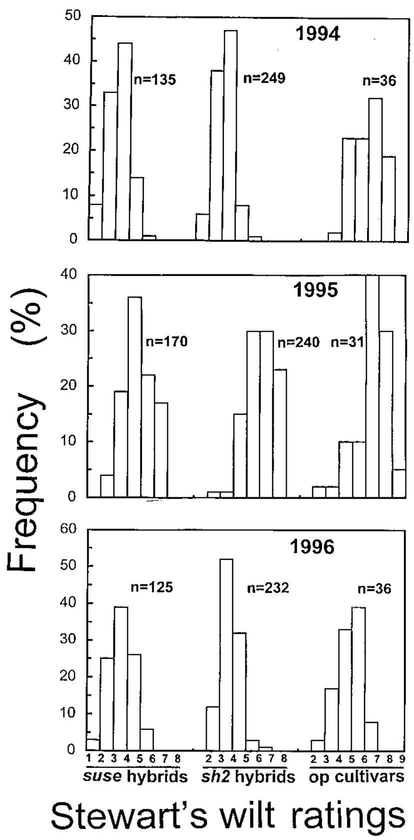

Fig. 1. Frequency distributions of Stewart's wilt ratings (1 to 9) for *su1*/*se1* hybrids, *sh2* hybrids, and open-pollinated sweet corn cultivars evaluated in 1994, 1995, and 1996.

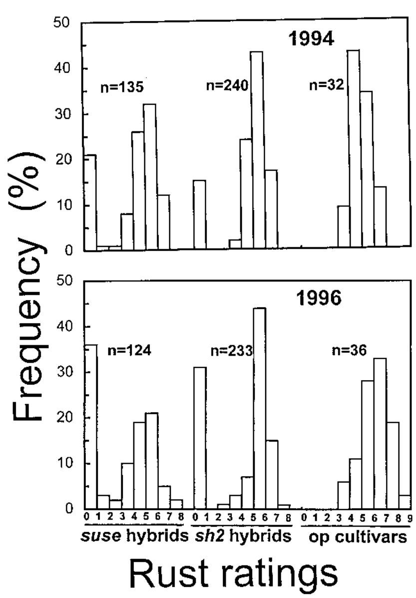

Fig. 2. Frequency distributions of common rust ratings (0 to 9) for *su1*/*se1* hybrids, *sh2* hybrids, and open-pollinated sweet corn cultivars evaluated in 1994 and 1996.

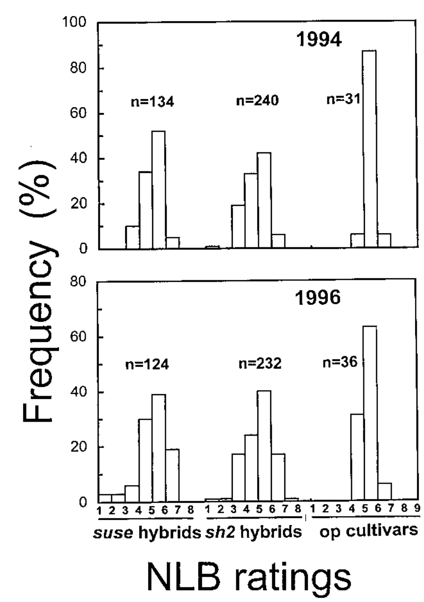

Fig. 3. Frequency distributions of northern leaf blight ratings (1 to 9) for *su1*/*se1* hybrids, *sh2* hybrids, and open-pollinated sweet corn cultivars evaluated in 1994 and 1996.

cluster analysis of disease ratings were considerably different from groups formed from isozyme variation (15) and morphological characteristics (16) (Table 2). The three OP cultivars that formed Group 4, with some resistance to all four diseases, each belonged to a different group based on isozyme variation and morphological characteristics. Golden Sunshine was grouped with isozyme Group 1, the Golden Bantam strains (15), and with morphological Group 2, which was characterized as mid- to late-maturing, high prolificacy, high kernel production, tall plants, dense foliage, 8 to 12 kernel rows on 8- to 15-cm ears, and good ear tip protection by husk leaves (16). Stowell's Evergreen was grouped with isozyme Group 2, the white-kernel group (15), and morphological Group 1, which included most of the widely used sweet corn cultivars and was characterized as variable for days to flowering, plant height, number of kernel rows, and ear length (16). Country Gentleman formed unique groups based on isozyme variation and morphology (15,16).

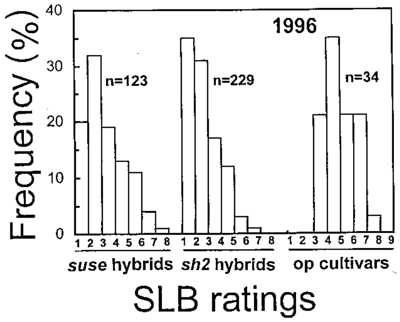

Fig. 4. Frequency distributions of southern leaf blight ratings (1 to 9) for *su1/se1* hybrids, *sh2* hybrids, and open-pollinated sweet corn cultivars evaluated in 1996.

DISCUSSION

Some of the OP cultivars evaluated in these trials had phenotypes intermediate to moderately resistant to Stewart's wilt, common rust, NLB, or SLB, but none of the cultivars were more resistant than the commercial hybrids with the least amount of disease. In general, distributions of ratings for rust, NLB, and SLB were less disperse for the OP cultivars than for commercial hybrids, possibly because of the small number of cultivars evaluated and/or some hybrids with high levels of resistance to these diseases. For Stewart's wilt ratings, OP cultivars and hybrids had about the same dispersion of variation as indicated by similar standard deviations and ranges, but the OP cultivars were more susceptible as a group than the hybrids, as indicated by higher means and maximum and minimum values (Table 1). The Bantam-type cultivars, which were well represented among the 36 cultivars evaluated,

Table 2. Disease ratings and cluster analysis groupings of 36 open-pollinated sweet corn cultivars and four standard hybrids

	Disease ratings[a]				Groups		
Cultivars and standard hybrids	Stewart's wilt	Common rust	NLB	SLB	Disease[b] reaction	Isozyme[c]	Morphology[d]
Anasazi	6.4	7.1	5.3	4.5	1	3	7
Aunt Mary's	5.5	5.2	5.0	3.4	3	1	2
Bantam Evergreen	5.5	5.3	4.9	3.4	3	1	1
Black Aztec	5.4	4.7	5.2	4.2	3	2	2
Buhl	5.5	4.8	6.2	6.5	5	1	...
Campbell	5.9	5.9	5.6	3.0	2	1	1
Clem Bennett	5.2	4.7	5.2	2.7	3	1	1
Country Gentleman	3.8	3.4	4.8	2.4	4	5	8
Dorinny	6.8	6.6	5.8	4.0	1	1	1
Golden Bantam WI	6.8	6.1	5.7	3.2	2	1	2
Golden Early Market	6.3	6.1	5.4	3.0	2	1	1
Golden Sunshine	3.6	4.4	4.7	2.8	4	1	2
Hayes White	6.3	5.1	5.4	4.9	5	2	1
Hidasta	5.8	5.7	5.4	4.9	5	3	6
Hooker's Sweet Indian	7.0	6.0	5.1	2.5	2	2	3
Hopi White	6.3	7.5	4.9	5.7	7	3	10
Howling Mob PI	5.8	5.7	5.2	3.5	3	2	1
Howling Mob SS	4.6	5.4	5.0	3.0	3	2	1
Kennedys White Midget	6.6	4.8	5.6	4.9	5	2	1
Lindsey Meyer Blue	6.8	4.3	5.6	3.5	2	1	2
Luther Hill	5.7	5.0	5.0	3.9	3	2	1
Malcombs	6.2	5.8	5.9	4.9	5	3	1
Mandan Red	7.3	7.4	5.5	3.6	1	1	5
Midnight Blue	4.7	4.5	5.6	4.5	3	1	1
Midnight Snack	5.2	5.9	5.3	5.3	5	1	1
No Name	5.5	5.6	4.9	3.6	3	1	4
Orchard Baby	6.6	6.0	6.2	4.7	5	1	3
Paiute Cross	6.3	7.2	5.7	7.3	7	1	9
Pease Crosby	6.8	5.4	6.3	3.3	2	2	1
Queen Anne	4.6	6.5	5.4	4.0	3	1	4
Red	3.9	3.6	4.3	4.5	6	3	...
Stowell's Evergreen	4.4	4.4	5.0	2.5	4	2	1
Sweet Baby Blue	7.3	6.2	5.3	3.5	1	2	3
Tuscarora	5.5	4.3	5.4	3.9	3	2	11
Whipples Yellow	5.5	4.9	5.6	3.1	3	1	1
Yukon Chief	7.2	6.6	5.9	....	...	1	3
Jubilee	6.7	4.8	6.3	1.8	2	...	...
Miracle	2.6	3.5	4.7	3.3	6	...	...
SummerSweet 7710	3.9	5.5	3.3	3.8	6	...	...
Sweetie 82	4.8	2.9	5.5	3.8	4	...	...
BLSD (k = 100)	1.4	0.7	0.9	2.7			

[a] Disease ratings (1 to 9) for Stewart's wilt, and (0 to 9) for common rust, northern leaf blight (NLB), and southern leaf blight (SLB).
[b] Seven groups formed from a hierarchical cluster analysis of reactions to Stewart's wilt, common rust, NLB, and SLB.
[c] Five groups formed from a hierarchical cluster analysis of isozyme variation (15).
[d] Nine groups formed from a hierarchical cluster analysis of 34 morphological characteristics (16).

were identified in the 1930s as being very susceptible to Stewart's wilt (3,7,8,14).

OP cultivars with moderate levels of resistance may provide sources of resistance alleles not present in commercial hybrids; however, none of the OP cultivars evaluated had levels of resistance sufficient to prevent economic losses under severe disease pressure. For example, Clinton and Singleton (3) noted that Golden Sunshine, an OP cultivar with low Stewart's wilt ratings in our trials, was "a little more resistant than Golden Early Market" in Connecticut in 1933, but the crop of Golden Sunshine was still unprofitable. In our trials, Golden Sunshine was rated 3.6 and Golden Early Market was rated 6.3 for Stewart's wilt.

Potential sources of resistance alleles among the 36 OP cultivars we screened include Golden Sunshine, Country Gentleman, Red, and possibly Stowell's Evergreen for Stewart's wilt; Country Gentleman, Red, and possibly Lindsey Meyer Blue, Tuscarora, Golden Sunshine, and Stowell's Evergreen for common rust; Red and possibly Golden Sunshine and Country Gentleman for NLB. The partial resistance of some of these cultivars, e.g., Golden Sunshine, Country Gentleman, Stowell's Evergreen, and Red, may be relatively diverse since these cultivars were placed in different groups based on isozyme and morphological variation (15,16). The partial resistance of Country Gentleman and Stowell's Evergreen probably already occurs in modern sweet corn germ plasm since these two cultivars and Golden Bantam were used prominently in the development of inbred lines (5,6,21).

Although we observed relatively little variation among individual plants of the OP cultivars, development of moderately resistant phenotypes from relatively susceptible OP cultivars is possible. For example, inbreds P39 and P51 were developed from Golden Bantam (4), one of the most Stewart's wilt–susceptible cultivars. P39 and P51 are the inbred parents of the hybrid Golden Cross Bantam, which was considered resistant compared with other sweet corn germ plasm in the 1930s (3) but has an intermediate Stewart's wilt reaction when compared with modern hybrids. Intermediate levels of Stewart's wilt resistance of Golden Sunshine may have been selected during the development of this cultivar from a cross of Gill's Early Market and Golden Bantam, since none of the other Bantam-type cultivars have levels of resistance equal to Golden Sunshine; nor did Mammoth White Cory, an ancestor of Gill's Early Market (14,20). Incorporation of known resistances from sources considered exotic by sweet corn breeders (e.g., field corn, tropical maize) probably will produce useable, resistant sweet corn germ plasm more quickly than incorporation of resistance alleles from relatively susceptible segregating OP cultivars.

The lack of correspondence between the cluster analysis for disease ratings and isozymes or morphology was not surprising. While disease resistance might be used as a factor in a phylogenetic analysis, the disease reaction of any given cultivar will depend on the selection pressure to which it has been exposed as well as on its genetic background.

Sweet corn breeders have greatly improved the resistance of modern germ plasm to Stewart's wilt, rust, and NLB. The use of *Rp*-genes for resistance to rust in nearly 33% of new commercial hybrids is alarming. The group of hybrids lacking *Rp*-resistance did not differ greatly from the OP cultivars we evaluated. Modern hybrids may be as vulnerable to a major epidemic of common rust as their OP ancestors because a widespread occurrence of biotypes of *P. sorghi* with virulence against the widely used *Rp* genes, primarily *Rp1d*, could cause substantial damage. Identification of additional sources of rust resistance, probably from sources other than sweet corn, and incorporation of these alleles into elite sweet corn germ plasm are highly appropriate.

The use of the genes *Ht1* and *HtN* in elite sweet corn hybrids, particularly among *sh2* hybrids, appears to be in conjunction with improvements in levels of partial resistance to NLB as compared with the OP cultivars. Possibly, partial resistance to NLB was obtained from field corn sources of *Ht1* and *HtN* that were used to improve NLB-resistance of *sh2* inbreds such as Fa32 (22). The improved levels of partial resistance to NLB in elite sweet corn germ plasm should not be threatened by selection for specific virulence among populations of *E. turcicum.* Identification of additional sources of resistance to NLB, Stewart's wilt, rust, and other pathogens of sweet corn could increase the genetic diversity of resistances being used in commercial hybrids and reduce the likelihood of severe epidemics.

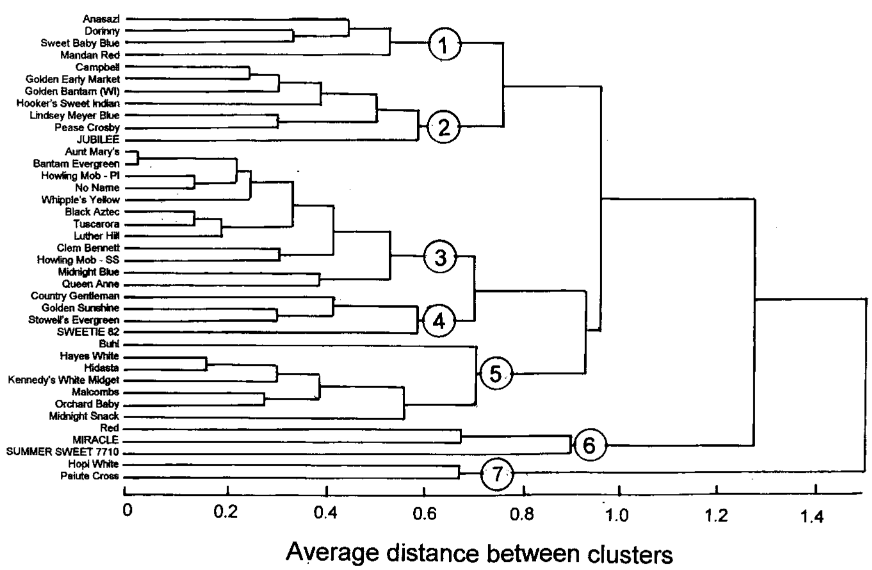

Fig. 5. Dendogram illustrating the relationships between 35 open-pollinated sweet corn cultivars and four standard hybrids (capital letters) based on a hierarchical cluster analysis of mean ratings for Stewart's wilt, common rust, northern leaf blight, and southern leaf blight.

Table 3. Groups of 35 open-pollinated sweet corn cultivars and four standard hybrids based on hierarchical cluster analysis of reactions to Stewart's wilt, common rust, northern leaf blight (NLB), and southern leaf blight (SLB), and group mean ratings for each disease

		Mean disease ratings			
Group[a]	**n**[b]	**Stewart's wilt**	**Common rust**	**NLB**	**SLB**
1	4	7.0[c]	6.4[d]	5.5[d]	3.9[d]
2	7	6.6	5.0	5.7	2.9
3	12	5.3	4.5	5.2	3.6
4	4	4.4	3.5	5.0	2.8
5	7	6.0	4.9	5.7	5.1
6	3	3.4	4.2	4.1	3.9
7	2	6.3	6.9	5.3	6.5

[a] Hierarchical cluster analysis groupings calculated using Ward's method.
[b] n = number of cultivars in each group.
[c] Stewart's wilt rated from 1 to 9 (18).
[d] Disease ratings on 0 to 9 scale, where the rating is approximately the square root of severity for rust, NLB, and SLB.

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